Stretching a long DNA molecule by use of local heating

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Stretching a long DNA molecule by use of local heating

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局所加熱によるＤＮＡの引き伸ばし：デキストラン高分子溶液下で長鎖DNAはランダムコイル状態で存在している。そこに集光した近赤外レーザーを照射するとDNAが引き伸ばされるという現象を見出した。レーザーの照射開始と同時にデキストラン溶液中でブラウン運動しているＤＮＡが伸張しはじめる。当て続けている間に初期状態の広がりの約4倍。使用しているＤＮＡの全長の半分弱まで伸ばされた。

Single molecule manipulation techniques have contributed to micro- or nanoscopic science and technology. Especially in polymer physics and biophysics, mechanical manipulations applied on a single DNA chain have revealed single polymer dynamics and detail processes of biomechanical reactions on nucleic acids. Such experiments have extended the DNA molecule to measure force spectroscopy at the chain edge, to visualize DNA fluctuation motion, or to identify localization and movement of proteins on the linear DNA. The stretching methods have been developed from several aspects, e.g., hydrodynamic flow of the solution [1)], alternative electric field [3)], and optical tweezers trapping microbeads attached at the chain end [2)], etc. Here, we present a new method for DNA stretch using convergence laser light irradiation. The long DNA chain dispersed in dextran solution is extended under focused infrared laser.

We used approximately 56 μm long double stranded DNA stained with fluorescent dye YOYO-1 to observe real time motion of a single DNA chain. Materials had been premixed in Milli-Q water as following final concentrations: 0.1 μM in base pair concentration DNA and 100 mg/ml dextran of which average molecular wight is 75040 Da. This mixed solution was sealed in a sample cell made from glass plates for microscopy observation. The approximately 50 μm thick enclosed solution was irradiated infrared laser light (CW 1064 nm, TEM_{00}) like a setting of laser trapping [4)].

Figure 1 shows a typical experimental result. We can see the floating DNA as in Fig. 1(a). This free DNA molecule is shrinking and swelling around 6 μm in long axis diameter (good solvent condition) before laser irradiation. The DNA starts spreading just after laser ON (Fig. 1(b)), and gradually transforms into linear shape as shown in Figs. 1(c-e). Each intersection pointed by white arrows indicates the laser focus in the picture. The DNA chain irradiated by

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the laser beam is weakly repelled from the laser focus, and radial DNA segments are extended as described in Fig. 1(f). Long axis length of the extended DNA is about 22 μm. In the end, we achieve the stretched DNA length distributes around 20 to 25 μm under this condition. That is four out of ten length of the DNA.

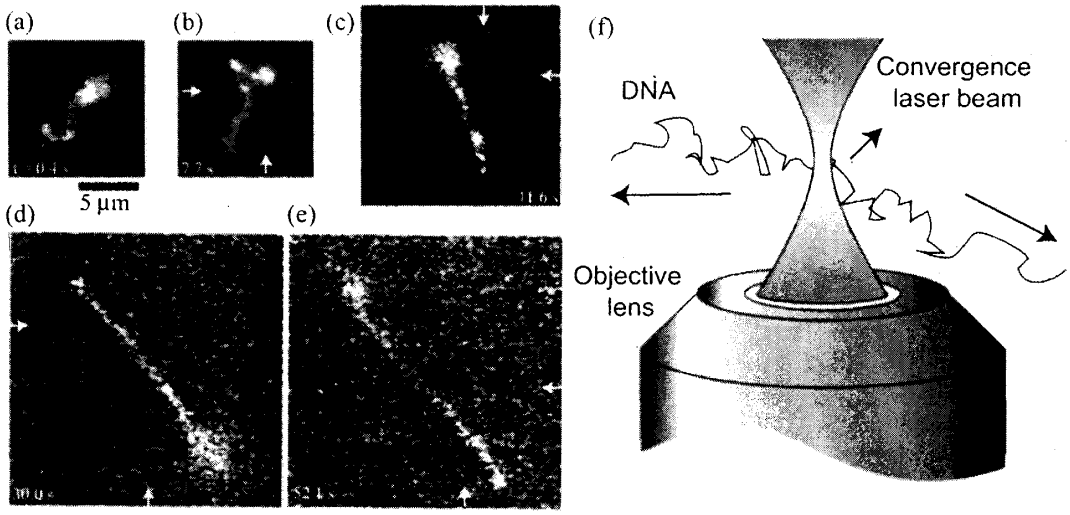

Figure 1: A single DNA molecule under laser irradiation. Lower-left numbers are time in each picture. The bar indicates 5 μm. (a) The DNA is free in the dextran solution without incident laser light. (b) The DNA starts stretching just some seconds after laser irradiation. (c) The same DNA at 11.6 s. (d,e) The extended DNA at 30.0 s and 52.1 s. (f) Schematic illustration of the phenomenon.

Next, we carry out control experiments whose medium has been changed from water into heavy water. Heavy water exhibits approximately 10 times lower absorption coefficient at the laser wavelength. The experimental result, in brief, is: a DNA is not extended by laser irradiation. This result suggests that the local heating given by the focused laser may induce the present phenomenon.

In conclusion, we demonstrate the novel method for stretching a long DNA molecule in aqueous solution. The characteristics, manipulating only a targeted DNA, may contribute the further development of nano-fabrication using DNA.

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